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ENVIRONMENTAL STUDY OF WATER AND SOIL REGIME ON SUSTAINABLE AGRICULTURE OF LUDHIANA DISTRICT, PUNJAB, INDIA

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ABSTRACT

Ludhiana district, the metropolitan state of Punjab, is the most vibrant and business center. The present investigation is to examine the suitability of soil andgroundwater quality for irrigation purpose and factor prevailing hydrochemistry by collecting 44 groundwater samples during pre and post monsoon. The physical and chemical analyses result shows that at some locations the concentration of EC, TDS, Ca^{2+}, Mg^{2+}, F^- and NO_3^{2-} exceeded the desirable limits of BIS which gives us cautions.The groundwater is safe for agricultural purpose with respect to %Na, RSC, SAR, MR, KI and Ca^{2+}/Mg^{2+} except for PI. The soil samples of the study area are within the limits except for Cadmium and Lead at some places. As per Wilcox majority of the groundwater samples are under good to permissible category. The USSL findings revealed that the groundwater samples falls under C_2S_1 and C_3S_1 category. The findings call for proper and immediate management plan to achieve agricultural sustainability and also to protect the invaluable resources of the study area.

KEYWORDS: Ludhiana, Groundwater Quality, Agricultural Sustainability, Management Plan

INTRODUCTION

Developing countries are facing acute problems of water resources in terms of quality and quantity. Groundwater irrigation started in 1950-51 on 6.5 million hectares (CGWB, 1992), which was increased to 46.5 million hectares in 2000-01 meeting about 70% of irrigation water requirements of the country. Groundwater is the major source of drinking water in both urban and rural areas in India. Unplanned urbanization, industrialization, overexploitation and unscientific disposal of treated and untreated effluent directly affect the quality and quantity of groundwater regime (Simeonov et al, 2003). Large stretches of water are heavily polluted by the adsorption and transportation of industrial, domestic and agricultural wastes ultimately results in environmental degradation and sustainability. The Green Revolution technology in the field of agriculture had put a great pressure on ecological balance, resulting in the fall of ground water table, soil resources deterioration and environmental pollution from farm chemicals. This imbalance results in global warming and ozone depletion through agricultural practices and also poisoned the environment.

SITE DESCRIPTION

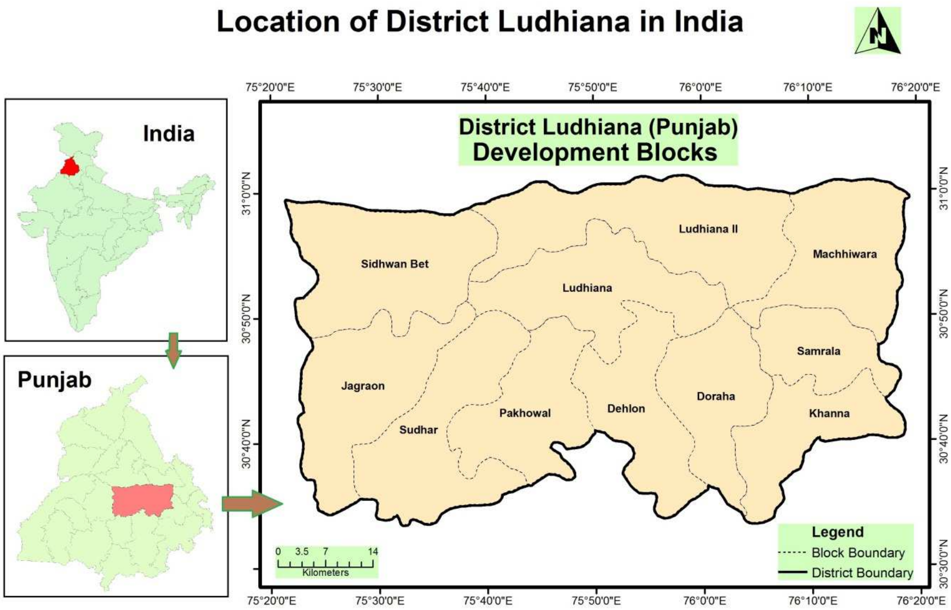

Figure 1: a) Map of India b) Map of Study Area

Ludhiana district is bounded between north latitude 30^0 33’ and 31^0 01’ and east longitude 75^0 25’ and 76^0 27’ falls in central part of Punjab.The district has four sub-divisions viz-Ludhiana, Khanna, Samrala and Jagraon and eleven development blocks viz.- Ludhiana, Mangat, Doraha, Khanna, Dehlon, Pokhwal, Samrala, Machiwara, Jagraon, Sidhwanbet and Sudhar. The climate of Ludhiana district is tropical steppe, hot and semi-arid with dry and very hot summer and cold winter except during monsoon season when moist air of oceanic origin penetrate into the district. There are four seasons in a year with hot season starts from mid March to last week of the June followed by the south west monsoon which lasts up to September. The transition period from September to November forms the post-monsoon season and the winter season starts late in November and remains up to first week of March.The normal annual rainfall of the district is 680 mm which is unevenly distributed over the area in 34 days. The south west monsoon, sets in from last week of June and withdraws in end of September, contributed about 78% of annual rainfall. July and August are the wettest months. Rest 22% rainfall is received during non-monsoon period in the wake of western disturbances and thunder storms. Generally rainfall in the district increases from southwest to northeast. Mean maximum temperature is 1.2°C (May & June) and mean minimum is 5.8^0C (January).

GEOMORPHOLOGY & SOIL TYPE

The district area is occupied by Indo-Gangetic alluvium. Mainly the area is plain and major drains are Satluj and its tributaries and Budhanala. The soil of this zone has developed under semi-arid condition. The soil is sandy loam to clayey with normal reaction (pH from 7.8 to 8.5).

HYDROGEOLOGY

In general the Ground water of the district is fresh except in and around Ludhiana city where the ground water is polluted due to industrial effluents. The lithological data of the boreholes indicate the presence of the first aquifer generally occurs between 10 and 30m. The second is between 50 and 120m. Third between 150-175m, the forth between 200-250m

and the fifth between 300-400m.

MATERIALS AND METHODS

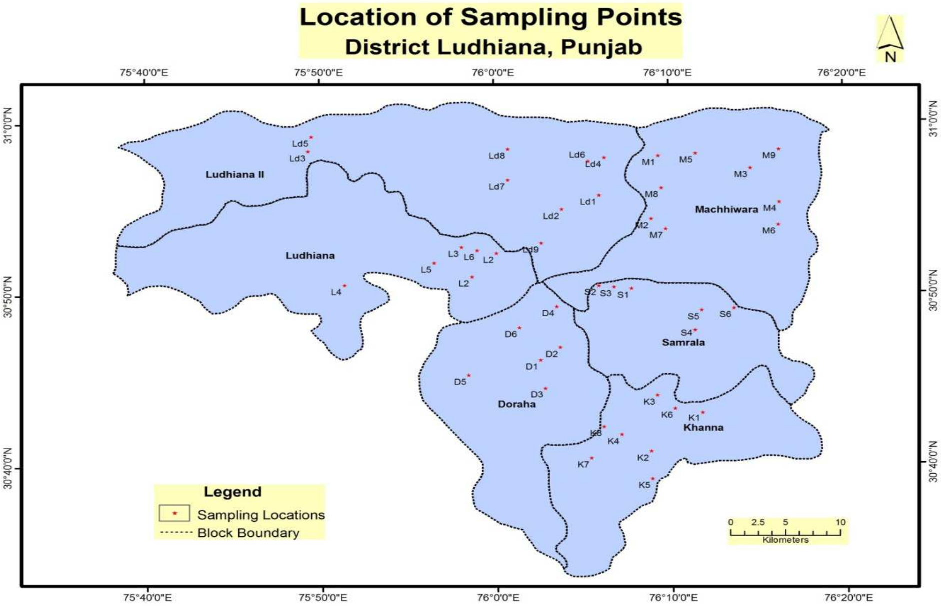

Figure 2: Map Showing Groundwater and Soil Sampling Points of Ludhiana District, Punjab, India

44 Groundwater samples were collected during May 2013 and October 2013 and were analyzed in laboratory. The water sampling has been carried out following the standard procedures. Good qualities, air tight plastic bottles with cover lock were used for sample collection and safe transfer to the laboratory for analysis. Analysis were done for pH and EC and the major ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^-, HCO_3^{2-}, CO_3^{2-} and NO_3^{2-}) using standard method. Temperature, pH, EC were determined at the time of sampling in the site. The determinations of immediate parameters were made within 2 days after sampling. Ca^{2+}, Mg^{2+}, CO_3^{2-} and HCO_3^{2-} were analyzed by titration. Na^+ and K^+ were measured by flame photometry and NO_3^{2-} and SO_4^{2-} by U.V Spectrophotometer. HCO_3^{2-} and Ca^{2+}were analyzed within 24 hour of sampling. The concentration of various soil parameters are calculated with ICAP-AES which means Inductively Coupled Argon Plasma – Atomic Emission Spectrometry

Table 1: Common Indices for Agricultural Water Quality Evaluation

SI. No.	Water Quality Indices	Sources
1.	Hardness (as $CaCO_3$)= Ca^{2+}X 2.50 + Mg^{2+}X4.12	Hounslow,1995
2.	SAR = $Na^+/\sqrt{((Ca^{2+}+Mg^{2+})/2)}$	Richards (1954)
3.	%Na = $((Na^+ + K^+)x100)/(Ca^{2+}+Mg^{2+}+Na^++K^+)$	Wilcox (1948)
4.	RSC= $(HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$	Eaton (1950)
5.	PI= $((Na^+ + \sqrt{HCO_3^-})x100)/(Ca^{2+}+Mg^{2+}+Na^+)$	Doneen (1964)
6.	KI= $Na^+/(Ca^{2+} + Mg^{2+})$	Kelly (1963)
7.	MR= $(Mg^{2+}x100)/(Ca^{2+} + Mg^{2+})$	Paliwal (1972)
*for 1, all cations and anions are expressed in mg/l and for 2-7 all are in meq/l		

RESULTS AND DISCUSSIONS

44 groundwater samples were collected from the study area for physico-chemical analysis and their results have been presented in **Table 2 and 3**. The brief details of quality parameters are as under:

Table 2: Showing Various Agricultural Parameters of Ground Water during Pre Monsoon

Count	pH	EC	TDS	TH	Ca	K	Mg	Na	HCO3	Cl	SO4	NO3	PO4	F	%Na	RSC	SAR	KI	PI	MR	Ca/Mg
L1	6.98	1310	1912	475.021	109.21	29.21	35.84	50.31	109	18.13	13.61	91.84	0.13	1.03	27.212	-6.06522	1.11491	0.27873	19.7954	37.5484	1.66323
L2	6.12	1276	1890	455.932	94.86	26.24	34.07	48.12	103	13.8	10.16	85.01	0.11	1.02	28.1313	-5.37364	1.18566	0.29641	20.652	39.6867	1.51974
L3	6.32	1123	1245	427.64	96.25	29.8	32.46	40.11	105	12.46	13.02	74.43	0.098	0.9	26.3911	-5.27083	0.99819	0.24955	19.8346	38.19	1.61849
L4	5.98	1054	1287	424.428	103.45	23.31	33.91	38.46	107	13.02	10.23	75.52	0.078	0.99	23.3841	-5.68061	0.90015	0.22504	18.813	37.521	1.66518
L5	6.24	982	1296	445.125	92.26	28.87	33.21	43.02	103	13.24	9.1	80.23	0.084	0.87	27.5158	-5.18616	1.0889	0.27223	20.3502	39.7399	1.51636
L6	6.11	930	1287	463.214	84.41	22.84	32.17	45.01	103	12.86	11.13	65.23	0.1	0.91	28.3123	-4.74814	1.21681	0.3042	21.7179	41.1152	1.43219
Ld1	7.1	1160	1367	468.289	86.01	20.84	27.83	39.06	105	13.23	12.05	50.85	0.095	0.78	26.6248	-4.43019	1.10491	0.27623	21.7831	37.2174	1.68692
Ld2	6.42	1082	1278	433.279	85.32	18.13	30.94	30.82	103	12.32	9.46	47.23	0.095	1.1	22.0562	-4.68782	0.84107	0.21027	19.6253	39.9173	1.50518
Ld3	7.01	946	1245	425.577	78.21	17.35	30.12	35.16	103	13.48	9.05	41.26	0.087	0.97	24.7802	-4.30113	1.02146	0.25537	21.3973	41.3683	1.41731
Ld4	6.21	832	1289	419.184	78.01	16.8	31.25	34.83	105	12.57	8.34	40.57	0.11	0.82	24.2541	-4.35232	0.99788	0.24947	21.3224	42.3268	1.36257
Ld5	6.11	852	1324	439.067	84.79	12.83	31.86	32.64	103	10.87	7.13	45.08	0.093	0.78	21.379	-4.7397	0.88355	0.22089	19.802	40.7725	1.45263
Ld6	5.87	987	1367	430.483	80.31	11.83	28.21	35.74	105	9.45	8.11	40.05	0.084	0.63	23.86	-4.20552	1.04932	0.26233	21.8926	39.1557	1.5539
Ld7	6.21	865	1278	397.878	79.16	8.32	31.04	38.11	103	10.6	7.4	40.06	0.056	0.71	23.4456	-4.41946	1.08571	0.27143	21.5439	41.8059	1.39201
Ld8	5.89	842	1256	383.455	77.61	10.56	27.83	37.03	102	8.9	6.3	42.2	0.078	0.78	24.5705	-4.1022	1.11591	0.27898	22.2253	39.6485	1.52217
Ld9	5.98	861	1276	430.058	75.02	9.84	26.61	42.56	103	10.83	8.11	38.02	0.088	0.93	27.4528	-3.86917	1.33255	0.33314	23.8877	39.3883	1.53883
M1	6.34	912	1812	441.444	74.02	8.1	29.12	43.31	105	9.83	8.02	37.89	0.092	0.79	26.7746	-3.99796	1.31772	0.32943	23.7076	41.8858	1.38744
M2	6.56	847	1723	415.679	78.31	8.9	28.11	45.13	107	9.23	7.8	41.04	0.045	0.92	27.3186	-4.07472	1.34729	0.33682	23.8519	39.6731	1.5206
M3	6.02	759	1602	408.724	72.01	9.05	26.12	41.17	103	9.01	7.5	35.04	0.067	0.98	27.313	-3.69371	1.33106	0.33276	24.2519	39.9234	1.50479
M4	6.16	873	1267	398.911	73.08	10.03	23.11	45.22	105	8.03	6.8	37.9	0.066	0.53	30.024	-3.46137	1.51829	0.37957	25.7925	36.683	1.72606
M5	6.56	886	1190	442.194	71.47	9.01	27.01	37.83	103	8.13	5.45	35.08	0.063	0.56	25.6745	-3.74268	1.21204	0.30301	23.5554	40.9115	1.4443
M6	6.14	746	1245	447.213	73.13	8.11	26.08	42.21	103	7.3	6.1	38.08	0.089	0.81	27.3475	-3.74071	1.35287	0.33822	24.2553	39.5172	1.53054
M7	5.89	776	1312	334.344	73.02	7.98	25.84	46.11	105	9.3	7.1	37.01	0.092	0.91	29.0232	-3.68325	1.48461	0.37115	25.1467	39.3324	1.54244
M8	6.24	749	1190	370.606	72.72	8.15	30.01	43.02	104	8.5	6.09	38.01	0.09	0.93	26.6175	-4.02919	1.30551	0.32638	23.51	43.0542	1.32265
M9	6.42	948	1234	270.179	70.89	8.05	25.13	45.01	103	6.7	7.9	37.02	0.1	0.84	29.1852	-3.56198	1.49172	0.37293	25.2918	39.374	1.53975
S1	7.11	1148	923	253.988	72.21	8.11	26.22	40.5	102	6.7	8.12	34.11	0.74	0.81	26.7246	-3.72731	1.30522	0.32631	23.9744	39.9486	1.50322
S2	6.54	1197	978	290.962	69.25	10.03	27.89	37.02	103	6.92	5.22	35.04	0.083	0.79	25.6772	-3.71539	1.19208	0.29802	23.5142	42.4578	1.35528
S3	6.6	1132	867	228.499	73.03	9.8	30.02	35.84	105	7.13	5.63	36.08	0.078	0.87	23.9428	-4.02754	1.08483	0.27121	22.4425	42.9581	1.32785
S4	7.12	980	890	259.625	70.89	10.05	29.11	37.8	103	8.04	7.11	35.83	0.096	0.93	25.4221	-3.88938	1.17923	0.29481	23.0721	42.9326	1.32923
S5	7.02	956	834	258.612	69.91	9.34	29.01	41.01	107	7.13	6.02	34.83	0.045	0.76	26.7983	-3.77159	1.29146	0.32287	24.1999	43.1896	1.31537
S6	7.01	734	845	225.739	68.71	9.15	30.98	42.05	103	6.19	5.12	34.09	0.063	0.82	26.8057	-3.94532	1.29879	0.3247	23.5663	45.2368	1.21059
D1	6.98	546	1123	194.696	69.01	8.22	27.65	45.22	105	7.23	6.04	38.05	0.023	0.75	28.8367	-3.65209	1.4644	0.3661	25.1224	42.3315	1.36231
D2	7.02	609	802	186.294	70.04	9.13	26.17	41.05	102	6.01	7.4	35.08	0.029	0.83	27.5963	-3.62576	1.34831	0.33708	24.406	40.6367	1.46083
D3	6.86	512	845	209.012	68.11	8.14	28.01	42.23	103	7.13	5.08	37.01	0.062	0.91	27.6095	-3.67407	1.37033	0.34258	24.4829	42.969	1.32726
D4	6.99	537	1023	253.781	67.35	9.17	25.12	42.83	102	6.18	6.03	36.17	0.068	0.57	29.1818	-3.41861	1.46402	0.366	25.4181	40.5936	1.46344
D5	7.01	612	1056	248.865	63.18	10.15	25.01	45.43	103	7.11	5.9	33.84	0.061	0.85	31.3575	-3.20593	1.61517	0.40379	26.6682	42.0368	1.37887
D6	6.87	547	1089	205.336	63.04	10.03	26.11	41.03	102	6.12	5.02	33.01	0.094	0.7	29.0797	-3.30652	1.43407	0.35852	25.5547	43.1434	1.31785
K1	6.98	830	1256	216.255	73.23	9.12	27.04	37.09	103	6.11	5.06	38.13	0.011	0.86	25.0934	-3.82417	1.17077	0.29269	23.1666	40.3515	1.47822
K2	7.01	759	1245	246.709	73.08	11.14	24.12	39.16	102	6.7	5.19	39.01	0.011	0.96	27.4109	-3.59362	1.29408	0.32352	24.2166	37.682	1.65378
K3	7.1	921	1056	276.51	70.18	10.02	29.05	42.01	103	7.16	5.02	39.06	0.016	0.91	27.3287	-3.85257	1.31927	0.32982	23.8567	43.1288	1.31864
K4	6.98	586	1023	352.098	69.6	9.54	27.11	41.83	103	5.96	5.18	40.31	0.082	0.68	27.8156	-3.66694	1.35915	0.33979	24.4454	41.6438	1.40132
K5	6.87	973	1034	319.485	71.03	9.93	27.17	43.01	105	6.19	5.07	40.03	0.078	0.85	28.147	-3.7033	1.37968	0.34492	24.6182	41.2039	1.42695
K6	6.98	801	1246	381.479	69.13	9.22	25.79	43.48	103	6.13	5.16	39.1	0.091	0.81	28.9305	-3.53725	1.44783	0.36196	25.1486	40.5993	1.4631
K7	7.04	785	1121	376.259	70.61	10.02	27.18	43.11	105	6.25	5.03	41.05	0.09	0.74	28.2778	-3.68527	1.3875	0.34688	24.6943	41.3566	1.41799
K8	7.01	815	1245	345.585	68.15	9.28	26.93	42.21	103	6.08	5.17	38.14	0.087	0.63	28.2152	-3.58703	1.39228	0.34807	24.7795	41.9939	1.3813

Table 3: Showing Various Agricultural Parameters of Ground Water during Post Monsoon

Count	pH	EC	TDS	TH	Ca	Mg	K	Na	HCO3	Cl	SO4	NO3	PO4	F	%Na	RSC	SAR	KI	PI	MR	Ca/Mg
L1	7.58	1317	1893	587.437	109.63	34.21	30.05	50.31	110	20.05	13.61	92.01	0.091	1.1	27.6514	-5.9336	1.13151	0.28288	31.1329	36.3745	1.74918
L2	6.42	1286	1891	553.131	95.88	33.01	25.43	48.12	103	14.08	10.18	85.4	0.062	0.98	28.0981	-5.3322	1.19265	0.29816	32.2298	38.6787	1.5854
L3	6.71	1127	1282	556.798	97.35	40.21	29.8	35.47	108	12.89	13.11	79.23	0.066	0.73	23.0871	-5.9086	0.80375	0.20094	26.3294	43.076	1.32148
L4	6.48	1063	1279	577.731	105.74	35.53	28.11	39.01	109	15.05	13.09	81.9	0.054	0.71	23.9508	-5.8839	0.88492	0.22123	27.6512	38.1035	1.62443
L5	6.95	1012	1294	550.611	94.87	38.87	31.63	41.65	108	14.89	9.1	85.8	0.029	0.96	26.0036	-5.687	0.97184	0.24296	29.0956	42.8778	1.33221
L6	6.58	934	1276	521.294	83.12	39.01	23.21	45.21	103	13.38	10.15	67.74	0.045	1	26.9453	-5.2529	1.13334	0.28333	31.5539	46.2317	1.16302
Ld1	7.24	1164	1342	530.002	86.61	34.46	21.54	35.23	105	14	12.05	55.32	0.032	0.83	23.6555	-5.0025	0.91173	0.22793	28.9848	42.161	1.37186
Ld2	6.59	1083	1269	536.364	89.16	35.5	20.01	30.82	109	14.03	10.15	50.06	0.038	0.68	21.1071	-5.137	0.77456	0.19364	27.0314	42.1784	1.37088
Ld3	6.98	956	1276	511.539	79.21	32.37	19.34	33.21	103	13.89	9.65	43.65	0.019	0.76	23.7687	-4.5311	0.92913	0.23228	29.8636	42.8145	1.33566
Ld4	6.57	842	1266	513.535	80.01	30.21	18.43	32.08	105	14.42	9.25	40.34	0.024	0.92	23.4979	-4.3566	0.91845	0.22961	30.1881	40.8896	1.44561
Ld5	6.72	869	1291	538.485	90.01	31.34	15.97	30.01	103	14.01	9.19	46.62	0.023	0.98	20.5656	-4.9313	0.78884	0.19721	27.1236	38.9461	1.56765
Ld6	6.43	976	1306	535.99	89.01	32.45	11.54	32.61	105	13.87	9.02	43.61	0.026	0.79	20.4501	-4.9449	0.85122	0.21281	28.1901	40.0447	1.49721
Ld7	6.53	871	1283	519.024	82.21	33.45	9.05	39.54	103	13.9	9.32	40.31	0.048	0.84	23.2469	-4.7547	1.06785	0.26696	31.4116	42.7079	1.34149
Ld8	6.41	856	1244	526.509	85.21	31.51	11.87	34.01	102	12.9	8.45	44.12	0.032	0.91	21.7409	-4.7462	0.92206	0.23052	29.3176	40.387	1.47605
Ld9	6.42	865	1249	501.135	75.04	29.06	10.97	40.32	103	12.85	8.32	38.75	0.024	0.8	26.1018	-4.0716	1.21805	0.30451	34.5769	41.503	1.40947
M1	6.84	914	1760	503.206	75.87	31.11	11.08	45.06	105	10.53	13.34	40.07	0.03	0.95	27.3285	-4.2447	1.31426	0.32856	35.5875	42.8972	1.33115
M2	6.78	915	1684	513.809	80.12	28.11	9.07	47.01	107	11.43	10.37	42.06	0.028	0.97	27.8121	-4.156	1.38412	0.34603	36.7307	39.1276	1.55574
M3	6.64	816	1536	500.611	74.83	27.21	10.02	45.16	103	10.04	11.07	39.54	0.019	0.84	28.4016	-3.91	1.40365	0.35091	37.1372	39.9827	1.50108
M4	6.83	949	1248	501.334	75.12	30.01	11.02	49.02	105	11.03	12.26	44.17	0.015	0.78	29.2424	-4.1206	1.46015	0.36504	37.5331	42.26	1.3663
M5	6.79	941	1187	495.072	72.61	29.01	9.11	43.22	103	9.53	8.11	40.11	0.093	0.79	27.2311	-3.9584	1.33184	0.33296	36.1936	42.2623	1.36618
M6	6.62	829	1239	500.586	74.82	28.01	9.04	40.11	103	8.32	7.9	39.86	0.013	0.7	25.8649	-3.9754	1.2323	0.30807	34.9455	40.6832	1.45802
M7	6.59	821	1319	496.344	73.12	26.74	8.23	47.21	105	10.09	7.04	38.86	0.024	0.69	29.226	-3.7618	1.49826	0.37456	38.6674	40.1194	1.49256
M8	6.57	815	1196	497.442	73.56	27.03	9.11	43.31	104	9.05	6.09	39.01	0.015	0.84	27.6967	-3.8218	1.36364	0.34091	36.9251	40.2344	1.48543
M9	6.53	954	1216	494.274	72.29	25.21	8.05	45.12	103	7.07	8.02	37.84	0.026	0.68	28.9599	-3.6314	1.47584	0.36896	38.5428	38.9837	1.56518
S1	6.95	1153	829	496.369	73.13	23.41	7.01	41.25	102	6.7	8.12	36.11	0.021	0.79	27.4768	-3.5375	1.37784	0.34446	37.5558	36.9671	1.70511
S2	6.68	1204	856	494.673	72.45	26.02	9.32	38.23	103	7.02	5.22	37.04	0.086	0.73	26.0643	-3.7052	1.23336	0.30834	35.5292	39.6856	1.51981
S3	6.69	1149	861	500.586	74.82	28.14	11.03	36.22	105	8.32	6.23	38.03	0.068	0.74	24.6635	-3.9533	1.11069	0.27767	33.6016	40.795	1.45128
S4	6.94	1021	857	489.334	70.31	29.02	10.11	39.85	103	9.01	7.23	38.23	0.075	0.69	26.4326	-3.8559	1.25068	0.31267	35.4178	43.0581	1.32244
S5	6.79	978	828	494.324	72.31	27.84	9.64	40.03	107	7.11	5.86	35.5	0.073	0.84	26.4172	-3.7831	1.25798	0.31449	35.9731	41.3615	1.41771
S6	6.91	783	854	485.516	68.78	23.06	9.05	42.85	103	7.05	5.22	34.26	0.069	0.75	29.5936	-3.297	1.49563	0.37391	39.5388	38.0514	1.62802
D1	7.04	557	1017	486.09	69.01	25.83	8.22	45.22	105	7.23	6.04	38.05	0.017	0.81	29.4201	-3.5024	1.50637	0.37659	39.3239	40.6786	1.45829
D2	7.08	615	786	488.835	70.11	28.01	9.22	40.44	102	8.11	8.9	36.31	0.022	0.92	26.7881	-3.7803	1.29063	0.32266	35.9862	42.2613	1.36623
D3	6.91	514	821	486.14	69.03	29.56	9.23	42.23	103	9.03	8.03	37.42	0.018	0.87	27.2619	-3.8429	1.3285	0.33213	36.388	43.9628	1.27465
D4	7.03	546	916	480.801	66.89	28.11	8.21	41.84	104	8.04	6.03	35.01	0.02	0.79	27.635	-3.6111	1.36956	0.34239	37.4498	43.5001	1.29885
D5	7.09	649	1019	474.114	64.21	27.14	10.03	43.76	105	7.83	6.01	34.33	0.021	0.68	29.6887	-3.3946	1.48845	0.37211	39.3786	43.642	1.29137
D6	7.08	552	1015	471.669	63.23	28.23	8.01	40.32	103	6.22	5.02	33.12	0.017	0.95	27.5105	-3.4731	1.3593	0.33983	37.5698	44.9932	1.22256
K1	7.08	831	1212	501.883	75.34	29.54	9.22	38.57	106	9.22	5.09	40.23	0.0149	0.93	24.7668	-4.0754	1.15457	0.28864	33.9958	41.8041	1.39211
K2	7.12	824	1209	499.613	74.43	28.35	8.23	37.83	103	6.99	5.22	39.11	0.011	0.86	24.6486	-3.9858	1.16011	0.29003	34.0141	41.1012	1.43302
K3	7.13	942	974	496.569	73.21	27.21	10.02	43.22	107	7.16	5.02	41.09	0.016	0.95	27.8826	-3.7717	1.36103	0.34026	37.2282	40.509	1.46859
K4	7.11	591	998	488.61	70.02	28.21	9.22	41.83	103	6.04	6.01	42.11	0.014	0.87	27.3326	-3.7763	1.33196	0.33299	36.5688	42.4664	1.3548
K5	7.09	981	982	493.65	72.04	29.23	7.08	43.07	105	7.96	5.07	40.89	0.015	0.91	26.7049	-3.9181	1.32898	0.33224	36.3925	42.6394	1.34525
K6	7.1	829	1194	488.71	70.06	28.11	8.71	44.02	103	8.02	6.83	41.35	0.016	0.94	28.1424	-3.7699	1.40334	0.35084	37.4203	42.3657	1.3604
K7	7.13	811	1081	496.968	73.37	29.63	9.06	43.02	107	6.04	5.86	42.36	0.015	0.87	26.8425	-3.9779	1.30598	0.3265	36.1465	42.5244	1.35159
K8	7.08	825	1211	488.161	69.84	28.53	7.89	40.89	103	6.08	5.03	40.23	0.013	0.96	26.5365	-3.7945	1.29769	0.32442	36.1197	42.8052	1.33617

Table 4: Showing Ground Water Parameters above Desirable and Permissible Limits

Parameters	Maximum Permissible Limit for Drinking Water	Desirable Limit for Drinking Water	No. of Ground Water Samples Analysed	No. of Samples above Permissible Limit	No. of Samples above Desirable Limit
EC	0-2000µS/cm	750µS/cm	44	Nil	09
TDS	2000mg/l	500mg/l	44	Nil	44
pH	No Relaxation	6.5 -8.5	44	Nil	Nil
Ca^{2+}	200mg/l	75mg/l	44	Nil	21
Mg^{2+}	100 mg/l	30 mg/l	44	Nil	12
Na^{+}	No Guidelines		44	Nil	Nil
K^{+}			44	Nil	Nil
Cl^{-}	1000mg/l	250mg/l	44	Nil	Nil
F^{-}	1.5	1	44	Nil	03
SO_4^{2-}	400	200	44	Nil	Nil
NO_3^{-}	No relaxation	45mg/l	44	Nil	08

Table 5: Showing Ground Water Parameters Suitable for Agriculture During Pre Monsoon

Parameters	Minimum	Maximum	Average
%Na	20.45	29.68	26.21
RSC	-5.93	-3.29	-4.24
SAR	0.77	1.50	1.21
KI	0.19	0.37	0.30
PI	26.32	39.53	34.28
MR	36.37	46.23	41.33
Ca/Mg	1.16	1.74	1.42

Table 6: Showing Ground Water Parameters Suitable for Agriculture during Post Monsoon

Parameters	Minimum	Maximum	Average
%Na	21.37	31.35	26.79
RSC	-6.06	-3.20	-4.06
SAR	0.84	1.61	1.25
KI	0.21	0.40	0.31
PI	18.81	26.66	23.21
MR	36.68	45.23	40.7
Ca/Mg	1.21	1.72	1.46

The ionic dominance pattern is in the order of Ca^{2+} > Mg^{2+}> Na^{+} > K^{+} among cations and HCO_3^{-}> NO_3^{--}> F^{-}> PO_4^{3--} among anions in both pre monsoon and post monsoon. The % Na and SAR value in the groundwater samples ranged from falls from 21.37meq/l to 31.35meq/l and 0.84meq/l to 1.61meq/l respectively which means that underground water is under good category. The RSC value rangedfrom-0.06meq/l to -3.20meq/l and thus falls under safe category.

Water can also be classified for agriculture suitability based on Kelly's Index. According to Kelly (1940) and Paliwal (1967) KI more than 1 indicates an excess level of sodium in waters and are unsuitable and less than 1 are suitable for agriculture. The values of KI in studied samples are less than 1 which revealed that groundwater is suitable for agriculture. Doneen (1964) evolved a criteria for assessing the suitability of water for agriculture based on Permeability Index (PI). According to PI value, water can be classified as Class I, Class II and Class III. The PI value of the most of the studied water samples falls under Class III category which means that water is unsuitable for agriculture.

Calcium and magnesium normally maintain the equilibrium in most of the water ecosystems. More of the magnesium, more effect on the crop yield (Sundary et al, 2009). Paliwal (1972) introduced an important ratio called an index of magnesium hazard. MR more than 50% indicated that water is unsuitable for agriculture and thus adversely affect the agriculture. The MR value ranged from 36.68meq/l to 45.23meq/l indicated that water is suitable for agriculture. The calcium/magnesium ratio is more than 1 which means that groundwater is calcium dominant.

In addition, graphical methods, Wilcox diagram and USSL diagram were adopted in the present study to verify the suitability of groundwater for agricultural use.

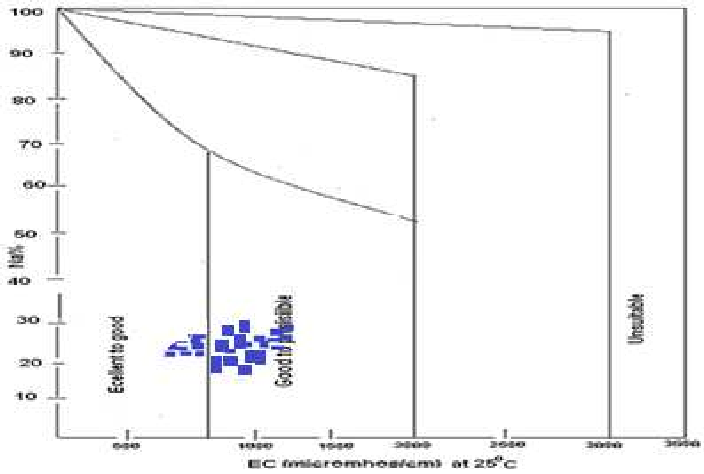

Figure 3: Wilcox Classification for Ground Water of Ludhiana District, Punjab, India

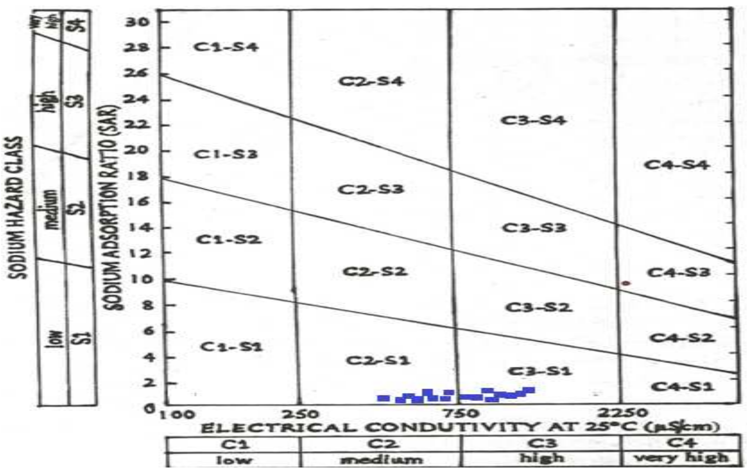

Figure 4: US Salinity Laboratory Classification of Ground Water of Ludhiana District, Punjab, India

The above figure indicated that as per Wilcox diagram16% of groundwater samplesfall under excellent to good category and 84% of groundwater samples falls under good to permissible category.As per USSL diagram 23% of the groundwater samples in pre and post monsoon falls under C_2-S_1 class which indicates medium salinity hazard but low alkali hazard and 73% of the samples falls under C_3-S_1 class which stands for high salinity hazard and low sodium hazard.

Table 7: Shows the Results of Various Soil Parameters of the Study Area

Soil Parameters	Range
Nitrogen	Lies between 49 -175(kg/hectare)
Phosphorus	Lies between 5.61 -18.1(kg/hectare)
Potassium	Lies between 115 -213(kg/hectare)
Zinc	Lies between 0.18 – 0.98 (mg/kg soil)
Iron	Lies between 3.6 – 12.2(mg/kg soil)
Copper	Lies between 0.05 -0.9(mg/kg soil)
Manganese	Lies between 1.63 -5.98(mg/kg soil)
Chloride	Lies between 0.1 – 1.21(mg/kg soil)
Cadmium	Lies between 0.05 – 10.9(ppm)
Lead	Lies between 0.41 – 9.9(ppm)

The results of various soil parameters are within the prescribed limit range except in some places high levels of cadmium and lead toxicity prevails. This may be attributed due to the leaching of metals in the soil due to industrial wastes.

CONCLUSIONS

Groundwater and quality of soil was evaluated for the agricultural sustainability of Ludhiana district. The physical and chemical analyses result shows that at some locations the concentration of EC, TDS, Ca^{2+}, Mg^{2+}, F^- and NO_3^{2-} exceeded the desirable limits of BIS which gives us cautions. The groundwater is safe for agricultural purpose with respect to %Na, RSC, SAR, MR, KI and Ca^{2+}/Mg^{2+} except for PI. The soil samples of the study area are within the limits except for Cadmium and Lead at some places. As per Wilcox majority of the groundwater samples are under good to permissible category. The USSL findings revealed that the groundwater samples falls under C_2S_1 i.e. medium salinity and low alkali hazard and C_3S_1 i.e. high salinity and low sodium hazard category. The findings call for proper and immediate management plan to achieve agricultural sustainability and also to protect the invaluable resources of the study area.

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